Naval Architecture / Ship Systems
S&T Newsletter #19
Global Developments in Marine Corrosion Control

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February 2004

Outline

- Overview of Marine Corrosion
- Methods of Corrosion Control
- Fora
- Conclusions

Overview of Marine Corrosion

- Types of corrosion
  - Localized: 70% of failures
    - Examples: crevice, pitting, stress, galvanic
    - Often caused by improper design or coating breakdown
  - Uniform: 30% of failures
    - Example: shell plate wastage
    - Controlled by proper application of coating, cathodic protection, good material selection (e.g., one that forms a protective oxide)
- Costs of corrosion
  - Corrosion control typically 10-15% of platform construction cost
  - Recent developments causing costs to rise to the point where *corrosion control = cost of ship's steel*
  - World cost for marine corrosion control ~ $13B / year

Sources: Marine Corrosion Forum, ABS, Bureau Veritas, Lloyd's Register

Commercial Drivers in Developing Marine Corrosion Control Techniques

- Catalyst: marine catastrophes, e.g., 1999 sinking of MV *Erika*
- New requirements by IMO, governments, classification societies
- More frequent inspections of steel + coatings, more consistent hull thickness measurements (gaugings)
- Also spurred S&T in long-life coatings, NDE, new designs
- Commercial owners are now asking for *no corrosion* over a 20 to 30 year service life

Principal Methods of Corrosion Control

- Coatings – the top priority for marine industry
  - Long-life coatings
  - Proper application & inspection procedures
  - NDE
- Materials
- Cathodic protection
- Design
- Modeling and simulation

Long-Life Coatings

- Long-life coatings under continual development by industry, mostly proprietary
  - Current technology 5-7 year life epoxy
  - Marine industry and US Navy looking for stronger, longer-lived warranties; stricter environmental compliance; extension to 20 years life
- Industry and academia researching shop primers for corrosion
  - Japan: Mitsui + Chugoku Paints R&D on primers for crude oil tanks
  - UK: University of Manchester program on zinc-silicate primers
- ONR / NRL – development of environmentally-compliant, rapid-cure, single-coat polyurethane coating under FNC
  - Coordination of single-coat efforts with other navies under TTCP
- US industry developing marine coatings to USN requirements, e.g., Sherwin-Williams' Fast Clad Edge Retentive Epoxy for ballast tanks (especially good for structural members with flanges)

Application and Inspection Procedures for Marine Coatings

- Correct application and inspection of coatings is ***the most important*** element of corrosion control
- NAVSEA Capital Investment Program ($45M FY02)
  - Replace sailors chipping and painting with professional teams
  - NRL & SUPSHIP provide QA to ensure correct procedures
- Overseas navies bringing ships under Classification standards (e.g, UK – Lloyd's, France -- BV, Denmark – DNV).
  - Includes commercially-derived rules and inspection of coatings by professional surveyors as part of acceptance process
  - Commercial practice gives more consistent standards and procedures (e.g., better record-keeping of gaugings) compared with former navy practices

Application and Inspection Procedures for Marine Coatings

- Inspection can be:
  - Rule-based: specific cycles for different areas (annual, biannual, every 5 years). Most common in industry
  - Risk-based: using models and simulations, including extensive FMEA. Coming into wider use
  - Condition-based: continuous monitoring of critical areas. Under development, depends on evolution of sensors

Nondestructive Evaluation (NDE) of Coatings and Structures

- **Major R&D focus worldwide**: detection of coating breakdown and structural wastage that cannot be seen by visual inspection (see ABS paper evaluating NDE efforts)
- ROV inspection of external / internal structure
  - Current state-of-art: video, ultrasonic gauging, EM potential
  - Offshore / oil industry pushing incorporation of new detection systems into ROVs
  - NRL developments for tank inspection:
    - Insertable Stalk Inspection System (w/ Everest Inc.)
    - Remotely Operated Paint Inspector (w/ Inuktun Ltd)

NDE of Coatings and Structures

- Embedded sensors & smart coatings
  - Vital for condition-based inspection / maintenance
  - Australia: DSTO & Monash University developing embedded fiber-optic corrosion sensors, with ONRG funding
  - US, UK industry: Several Joint Industry Projects (JIPs) proposed to evaluate sensors such as electrochemical impedance spectroscopy, and smart coatings (piezoelectric or electro constrictive).
- Portable sensors (handheld or ROV)
  - US, UK industry: Several JIPs proposed to evaluate sensor technologies such as thermal imaging, fluorescence (in conjunction with smart coatings), improved ultrasound, direct DC, magnetic flux,
  - NRL: Polarization sensors
  -

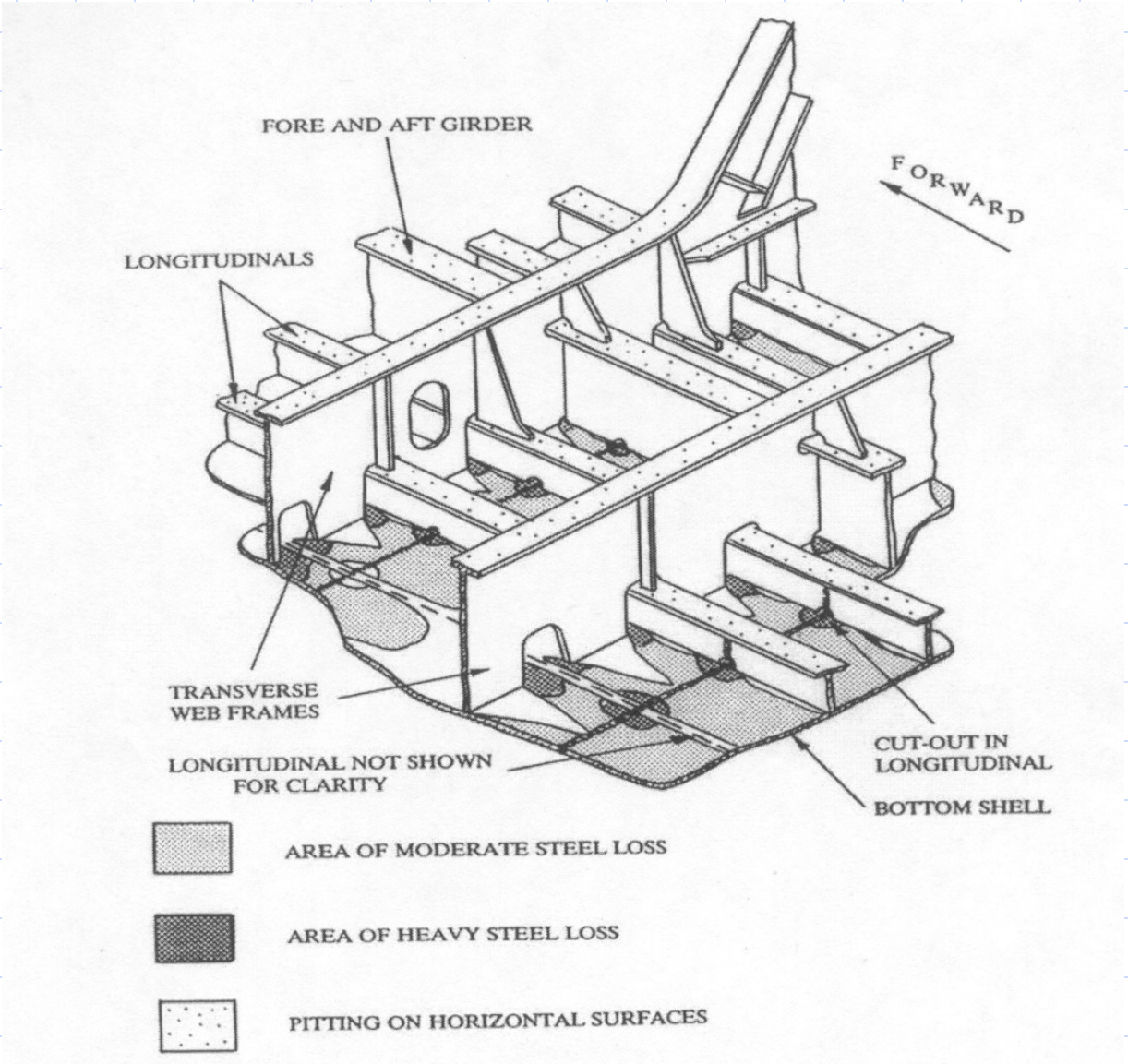
Materials

- Japan:
  - National Institute for Materials Science “Ultra-steel” stainless steel (high N, low-Ni) under development
  - Nippon Steel developed titanium-clad bridge piers
- UK: British Titanium low-cost alloy (ONRG NICOP)
- US Navy: Stainless-steel alloy development
- Marine industry interest in alternative materials appears to be low at the moment

Cathodic Protection Systems

- US Navy: Leaders in Impressed Current Cathodic Protection (ICCP) systems for hull, tanks, propellers
- Extensive navy-to-navy cooperation under TTCP, ABCANZ, NATO
- Major emphasis on modeling & simulation, as proper design is very important to effectiveness

Design to Reduce Corrosion Risk



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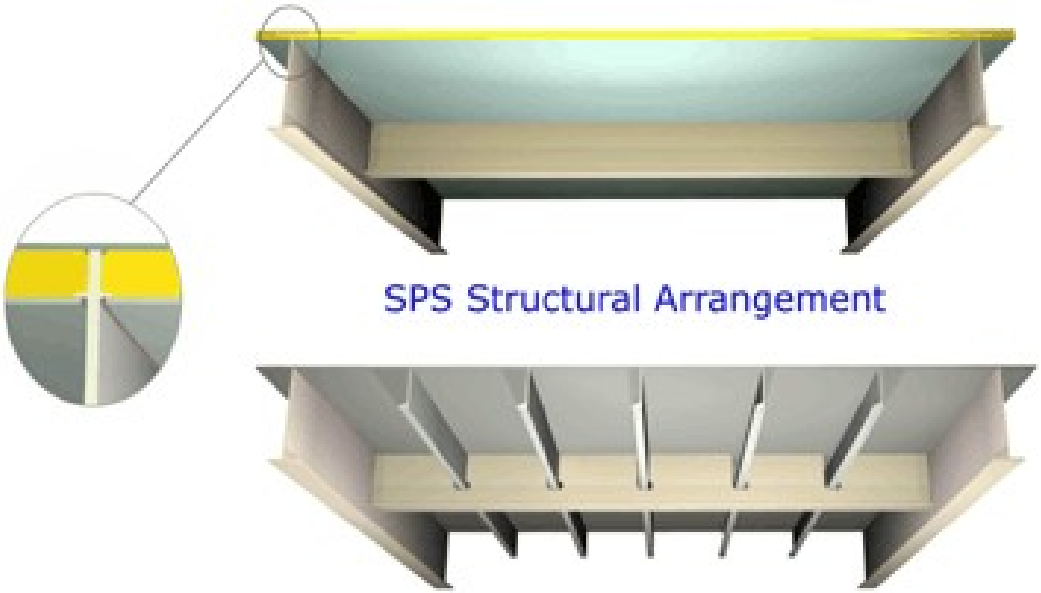

- Sandwich Plate System, developed by Intelligent Engineering
- Simplified structure has fewer welds, joints for localized corrosion
- Identified & promoted by ONRG for use on US Navy programs; currently under evaluation

Modeling and Simulation

- Vital for risk-based inspection / maintenance
- US Navy:
  - Large-scale physical modeling and computational modeling of ICCP
  - Extensive navy-to-navy cooperation (TTCP, ABCANZ, etc.), especially with France
  - Extensive cooperation / coordination with international industries (e.g., Beasy, Frazer-Nash) and academia (e.g., Tokyo Institute of Technology)

Modeling and Simulation

- USA:
  - Biocorrosion research & modeling at University of Delaware
- Australia:
  - DSTO & Monash University developing modeling of ultrasonic surface waves, with ONRG funding
  - University of Newcastle developing stochastic modeling of short-and long-term corrosion based on environmental factors
- European JIPs aimed at calibrating corrosion models with field experiments

Some Fora

- Marine Corrosion Forum
  - Industry group, mostly UK. Heavy involvement of offshore oil/gas companies Some MoD participation
- European Federation of Corrosion
  - Covers broad range of topics, with sub-group dedicated to marine corrosion
- Shipbuilding Research Association of Japan
  - Ad hoc teams formed for specific subjects, e.g., cargo oil tank corrosion
- NATO; TTCP; ABCANZ; bilateral DEAs / IEAs
  - Very strong NRL / NAVSEA participation and connectivity with other navies in areas such as ICCP modeling, coating standards, biofouling.
- ONR and ONRG sponsored symposia
  - Corrosion Science in the 21st Century, July 2003
  - RINA International Congress on Marine Corrosion, July 2004
  - Maritime Environment Conference, September 2004

Conclusions

- Corrosion control of high interest to global marine industry, with many players attempting to solve the same problems
- US Navy modus operandi has traditionally been:
  - Navy-funded, industry-led programs aimed at solving Navy problems
  - International cooperation with other navies
- Other navies are increasingly leveraging commercial opportunities
  - Use of commercially-based classification rules
  - Involvement in Joint Industry Projects (JIPs)

Conclusions

- US Navy and navy-related industries should take advantage of increasing number of Joint Industry Projects (JIPs) worldwide that are aimed at solving corrosion control problems
  - Advantages: costs and risks spread over many partners; products likely to be available over a wide sector of market, further reducing costs
  - Disadvantages: proprietary; unsatisfactory results if goals are not aligned
  - Many European navies and US Coast Guard participate in JIPs (though few examples for marine coatings)
  - ONRG uniquely placed to identify international JIPs and to facilitate participation by both US Navy and navy-related industry

Acknowledgements

- ONRG ADs
- ONR Reserve Unit
- US Naval Research Laboratory
- American Bureau of Shipping (USA)
- Bureau Veritas (FR)
- University of Newcastle (AU)
- MARIN (NL)
- Intelligent Engineering (UK)
- Lloyd's Register (UK)
- Marine Corrosion Forum (UK)
- MoD (UK)
- Royal Institution of Naval Architects (UK)
- University of Southampton (UK)